the need to replace programmers who leave the labor force or transfer to other occupations such as manager or systems analyst.

Despite numerous openings, a number of factors will continue to moderate employment growth. The consolidation and centralization of systems and applications, developments in packaged software, advanced programming languages and tools, and the growing ability of users to design, write, and implement more of their own programs means more of the programming functions can be transferred to other types of workers. Furthermore, completion of Year 2000 work will mean that many programmers will need to be retrained and redeployed in other areas. And, as the level of technological innovation and sophistication increases, programmers should continue to face increasing competition from programming businesses overseas where much routine work can be outsourced at a lower cost.

Nevertheless, employers will continue to need programmers with strong technical skills who understand an employer's business and its programming needs. Given the importance of networking and the expansion of client/server environments, organizations will look for programmers who can support data communications and help implement electronic commerce and intranet strategies. Demand for programmers with strong object-oriented programming capabilities and technical specialization in areas such as client/server programming, multimedia technology, and graphic user interface (GUI), should arise from the expansion of intranets, extranets, and World Wide Web applications. Programmers will also be needed to create and maintain expert systems and embed these technologies in more and more products.

As programming tasks become increasingly sophisticated and an additional level of skill and experience is demanded by employers, graduates of 2-year programs and people with less than a 2-year degree or its equivalent in work experience should face strong competition for programming jobs. Competition for entry-level positions, however, can also affect applicants with a bachelor's degree. Prospects should be best for college graduates with knowledge of, and experience working with, a variety of programming languages and tools—including C++ and other object-oriented languages like Visual Basic and Java, as well as newer, domain-specific languages that apply to computer networking, data base management, and Internet application development. Because demand fluctuates with employers' needs, job seekers should keep up to date with the latest skills and technologies. Individuals who want to become programmers can enhance their prospects by combining the appropriate formal training with practical work experience.

Earnings

Median annual earnings of computer programmers were $47,550 in 1998. The middle 50 percent earned between $36,020 and $70,610 a year. The lowest 10 percent earned less than $27,670; the highest 10 percent earned more than $88,730. Median annual earnings in the industries employing the largest numbers of computer programmers in 1997 were:

Personnel supply services	$53,700
Computer and data processing services	48,900
Telephone communications	48,800
Professional and commercial equipment	47,700
Management and public relations	46,400

According to the National Association of Colleges and Employers, starting salary offers for graduates with a bachelor's degree in computer programming averaged about $40,800 a year in 1999.

Programmers working in the West or Northeast earned somewhat more than those working in the South or Midwest. On average, systems programmers earn more than applications programmers.

According to Robert Half International, average annual starting salaries in 1999 ranged from $38,000 to $50,500 for applications development programmers and from $49,000 to $63,000 for systems programmers. Average starting salaries for Internet programmers ranged from $48,800 to $68,300.

Related Occupations

Other professional workers who must be detail-oriented include computer scientists, computer engineers, systems analysts, database administrators, statisticians, mathematicians, engineers, financial analysts, accountants, actuaries, and operations research analysts.

Sources of Additional Information

State employment service offices can provide information about job openings for computer programmers. Also check with your city's chamber of commerce for information on the area's largest employers.

For information about certification as a computing professional, contact:

☛ Institute for Certification of Computing Professionals (ICCP), 2200 East Devon Ave., Suite 268, Des Plaines, IL 60018. Internet: **http://www.iccp.org**

Further information about computer careers is available from:

☛ The Association for Computing Machinery (ACM), 1515 Broadway, New York, NY 10036. Internet: **http://www.acm.org**

☛ Institute of Electrical and Electronics Engineers—United States of America, 1828 L St. NW., Suite 1202, Washington, DC 20036. Internet: **http://www.ieee.org**

Mathematicians

(O*NET 25319A, 25319B, and 25319C)

Significant Points

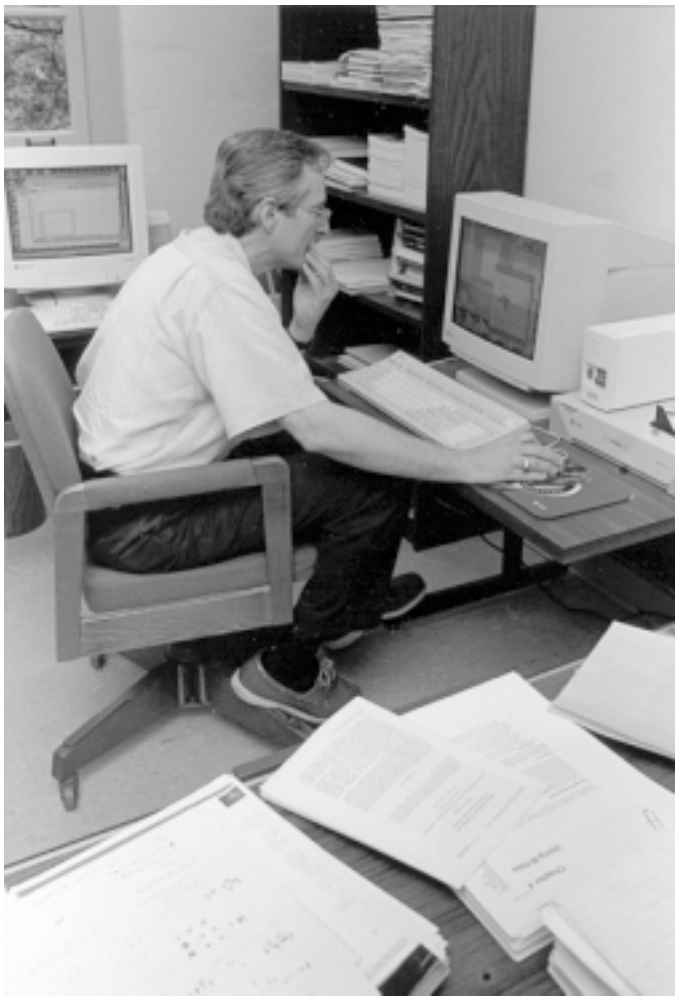
- Employment is expected to decline because few mathematics graduates get jobs that have the title mathematician.
- Bachelor's and master's degree holders with extensive training in mathematics and a related discipline, such as computer science, economics, engineering, or operations research, should have good employment opportunities in related occupations.

Nature of the Work

Mathematics is one of the oldest and most fundamental sciences. Mathematicians use mathematical theory, computational techniques, algorithms, and the latest computer technology to solve economic, scientific, engineering, physics, and business problems. The work of mathematicians falls into two broad classes—theoretical (pure) mathematics and applied mathematics. These classes, however, are not sharply defined and often overlap.

Theoretical mathematicians advance mathematical knowledge by developing new principles and recognizing previously unknown relationships between existing principles of mathematics. Although they seek to increase basic knowledge without necessarily considering its practical use, such pure and abstract knowledge has been instrumental in producing or furthering many scientific and engineering achievements.

Applied mathematicians, on the other hand, use theories and techniques, such as mathematical modeling and computational methods, to formulate and solve practical problems in business, government, engineering, and the physical, life, and social sciences. For example, they may analyze the most efficient way to schedule airline routes between cities, the effect and safety of new drugs, the aerodynamic characteristics of an experimental automobile, or the cost effectiveness of alternate manufacturing processes for a businesses. Applied mathematicians working in industrial research and development may develop or enhance mathematical methods when solving a difficult problem. Some mathematicians, called cryptanalysts, analyze and decipher encryption systems designed to transmit military, political, financial, or law enforcement-related information in code.



Mathematicians use computers extensively to analyze data and develop models.

Applied mathematicians start with a practical problem, envision the separate elements of the process under consideration, and then reduce the elements into mathematical variables. They often use computers to analyze relationships among the variables and solve complex problems through developing models with alternate solutions.

Much of the work in applied mathematics is done by individuals with titles other than mathematician. In fact, because mathematics is the foundation upon which so many other academic disciplines are built, the number of workers using mathematical techniques is much greater than the number formally designated as mathematicians. For example, engineers, computer scientists, physicists, and economists are among those who use mathematics extensively. Some professionals, including statisticians, actuaries, and operations research analysts, actually are specialists in a particular branch of mathematics. (For more information, see statements on actuaries, operations research analysts, and statisticians elsewhere in the *Handbook*.)

Working Conditions

Mathematicians usually work in comfortable offices. They are often part of an interdisciplinary team that may include economists, engineers, computer scientists, physicists, technicians, and others. Deadlines, overtime work, special requests for information or analysis, and prolonged travel to attend seminars or conferences may be part of their jobs. Mathematicians who work in academia usually have a mix of teaching and research responsibilities.

Employment

Mathematicians held about 14,000 jobs in 1998. In addition, about 20,000 persons held mathematics faculty positions in colleges and universities in 1998, according to the American Mathematical Society. (See the statement on college and university faculty elsewhere in the *Handbook*.)

Many nonfaculty mathematicians work for Federal or State governments. The Department of Defense is the primary Federal employer of mathematicians, accounting for almost three-fourths of the mathematicians employed by the Federal Government. In the private sector, major employers include research and testing services, educational services, security and commodity exchanges, and management and public relations services. Within manufacturing, the drug industry is the key employer. Some mathematicians also work for banks, insurance companies, and public utilities.

Training, Other Qualifications, and Advancement

A doctoral degree in mathematics is usually the minimum education needed for prospective mathematicians, with the exception of the Federal Government. In the Federal Government, entry-level job candidates usually must have a 4-year degree with a major in mathematics or a 4-year degree with the equivalent of a mathematics major—24 semester hours of mathematics courses.

In private industry, job candidates typically need a Ph.D. degree to obtain jobs as mathematicians. Most of the positions designated for mathematicians are in research and development laboratories as part of technical teams. These research scientists engage in either basic research on pure mathematical principles or in applied research on developing or improving specific products or processes. The majority of those with a bachelor's or master's degree in mathematics who work in private industry do so not as mathematicians, but in related fields such as computer science, where they have titles such as computer programmer, systems analyst, or systems engineer.

A bachelor's degree in mathematics is offered by most colleges and universities. Mathematics courses usually required for this degree are calculus, differential equations, and linear and abstract algebra. Additional courses might include probability theory and statistics, mathematical analysis, numerical analysis, topology, discrete mathematics, and mathematical logic. Many colleges and universities urge or require students majoring in mathematics to take courses in a field that is closely related to mathematics, such as computer science, engineering, life science, physical science, or economics. A double major in mathematics and another discipline such as computer science, economics, or one of the sciences is particularly desirable to many employers. A prospective college mathematics major should take as many mathematics courses as possible while in high school.

In 1998, about 240 colleges and universities offered a master's degree as the highest degree in either pure or applied mathematics; and about 200 offered a Ph.D. in pure or applied mathematics. In graduate school, students conduct research and take advanced courses, usually specializing in a subfield of mathematics.

For work in applied mathematics, training in the field in which the mathematics will be used is very important. Mathematics is used extensively in the fields of physics, actuarial science, statistics, engineering, and operations research. Computer science, business and industrial management, economics, chemistry, geology, life sciences, and behavioral sciences are likewise dependent on applied mathematics. Mathematicians also should have substantial knowledge of computer programming because most complex mathematical computation and much mathematical modeling is done on a computer.

Mathematicians need good reasoning ability and persistence in order to identify, analyze, and apply basic principles to technical problems. Communication skills are also important, as mathematicians must be able to interact and discuss proposed solutions with people who may not have an extensive knowledge of mathematics.

Job Outlook
Employment of mathematicians is expected to decrease through 2008. The number of jobs available for workers whose educational background is solely in mathematics is not expected to increase significantly. Those whose educational background includes the study of a related discipline such as statistics or computer science will have better job opportunities. Advancements in technology usually lead to expanding applications of mathematics, and more workers with knowledge of mathematics will be required in the future. Many of these workers have job titles that reflect their occupation rather than the discipline of mathematics used in their work.

Bachelor's degree holders in mathematics are usually not qualified for most jobs as mathematicians. However, those with a strong background in computer science, electrical or mechanical engineering, or operations research should have good opportunities. In addition, bachelor's degree holders who meet State certification requirements may become high school mathematics teachers. (For additional information, see the statement on kindergarten, elementary, and secondary school teachers elsewhere in the *Handbook*.)

Holders of a master's degree in mathematics will face very strong competition for jobs in theoretical research. Similar to bachelor's degree holders, however, job opportunities in applied mathematics and related areas, such as computer programming, operations research, and engineering design will be more numerous. Academia continues to produce more Ph.D.s than the number of university positions available, so many of these mathematicians will need to find employment in industry and government.

Earnings
Median annual earnings of mathematicians were $49,120 in 1998. The middle 50 percent earned between $33,420 and $77,300. The lowest 10 percent had earnings of less than $25,150, while the top 10 percent earned over $101,990.

According to a 1999 survey by the National Association of Colleges and Employers, starting salary offers for mathematics graduates with a bachelor's degree averaged about $37,300 a year and for those with a master's degree, $42,000. Doctoral degree candidates averaged $58,900. The average annual salary for mathematicians employed by the Federal Government in supervisory, nonsupervisory, and managerial positions was $69,000; for mathematical statisticians, $69,000; and for cryptanalysts, $61,100 in early 1999.

Related Occupations
Other occupations that require extensive knowledge of mathematics or, in some cases, a degree in mathematics include actuary, statistician, computer programmer, systems analyst, systems engineer, and operations research analyst. A strong background in mathematics also facilitates employment in engineering, economics, finance, and physics.

Sources of Additional Information
For more information about careers and training in mathematics, especially for doctoral level employment, contact:
☛ American Mathematical Society, Department of Professional Programs and Services, P.O. Box 6248, Providence, RI 02940-6248.
Internet: **http://www.ams.org**

For more information about careers and training in mathematics, contact:
☛ Mathematical Association of America, 1529 18th St. NW., Washington, DC 20036. Internet: **http://www.maa.org**

For a 1998 resource guide on careers in mathematical sciences, contact:
☛ Conference Board of the Mathematical Sciences, 1529 18th St. NW., Washington, DC 20036. Internet: **http://www.maa.org/cbms/cbms.html**

For specific information on careers in applied mathematics, contact:
☛ Society for Industrial and Applied Mathematics, 3600 University City Science Center, Philadelphia, PA 19104-2688.
Internet: **http://www.siam.org/alterindex.htm**

Information on obtaining a job as a mathematician with the Federal Government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; TDD (912) 744-2299. This number is not toll free and charges may result. Information may also be obtained through their Internet site: **http:// www.usajobs.opm.gov**

Operations Research Analysts

(O*NET 25302)

Significant Points

- Individuals with a master's or Ph.D. degree in management science, operations research, or a closely related field should have good job prospects.
- Employment growth is projected to be slower than average.

Nature of the Work
Operations research (OR) and management science are terms that are used interchangeably to describe the discipline of applying quantitative techniques to make decisions and solve problems. Many methods used in operations research were developed during World War II to help take the guesswork out of missions such as deploying radar, searching for enemy submarines, and getting supplies where they were most needed. Following the war, numerous peacetime applications emerged, leading to the use of OR and management science in many industries and occupations.

The prevalence of operations research in the Nation's economy reflects the growing complexity of managing large organizations that require the efficient use of materials, equipment, and people. OR analysts determine the optimal means of coordinating these elements to achieve specified goals by applying mathematical principles to organizational problems. They solve problems in different ways and propose alternative solutions to management, which then chooses the course of action that best meets their goals. In general, OR analysts are concerned with issues such as strategy, forecasting, resource allocation, facilities layout, inventory control, personnel schedules, and distribution systems.

The duties of the operations research analyst vary according to the structure and management philosophy of the employer or client. Some firms centralize operations research in one department; others use operations research in each division. Some organizations contract operations research services with a consulting firm. Economists, systems analysts, mathematicians, industrial engineers, and others may apply operations research techniques to address problems in their respective fields. Operations research analysts may also work closely with senior managers to identify and solve a variety of problems.

Regardless of the type or structure of the client organization, operations research in its classical role of carrying out analysis to support management's quest for performance improvement entails a similar set of procedures. Managers begin the process by describing the symptoms of a problem to the analyst, who then formally defines the problem. For example, an operations research analyst for an auto manufacturer may be asked to determine the best inventory level for each of the parts needed on a production line and to determine the number of windshields to be kept in inventory. Too